U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 231.

SPRAYING FOR CUCUMBER AND MELON DISEASES.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., August 15, 1905.

SIR: I have the honor to transmit herewith an article entitled "Spraying for Cucumber and Melon Diseases," by Mr. W. A. Orton, Pathologist, and recommend its publication as a Farmers' Bulletin.

This paper was submitted, with a view to publication, by Mr. A. F. Woods, Pathologist and Physiologist of this Bureau. It is for the most part the result of experiments conducted during 1904 and 1905, in cooperation with the South Carolina Agricultural Experiment Station, at Charleston, S. C., to control the downy mildew. An account of these experiments, with other matters of local interest, is also to be published by the South Carolina station.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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SPRAYING FOR CUCUMBER AND MELON DISEASES.

INTRODUCTION.

The purpose of this bulletin is to describe briefly the common diseases of cucurbits and to state the practical requirements for their control. Since adequate apparatus must be available before spraying can be generally practiced, the essential points of a good sprayer are described in detail.

It should be emphasized that success in spraying is a question of methods. It depends absolutely upon intelligent oversight, suitable apparatus, and thorough application. All the failures investigated have been due to errors in methods or lack of thoroughness.

DESCRIPTIONS OF DISEASES.

Several diseases attack the leaves of cucumbers and melons in this country. Downy mildew, leaf-blight, and anthracnose are the most common, though there are several others of less importance. The parasitic fungi which cause these troubles are quite distinct in their nature, but produce rather similar effects on the foliage. From the standpoint of the farmer they may be considered together, since the treatment for all is practically the same. It is well to know their exact characters, however, especially since there are a number of other maladies, due to bacteria, soil and climatic conditions, and to insects, which do not yield so readily to spraying, and may be confused with the diseases to be described.

DOWNY MILDEW.

Peronoplasmopara cubensis (B. & C.) Clint.

Downy mildew, the most destructive of all cucurbit diseases, is especially injurious to cucumbers, but also attacks melons, squashes, pumpkins, gourds, and other related vines.

Appearance.—The first indication of downy mildew in the field is a yellowing of the older leaves in the center of the plant. Faintly defined angular spots bordered by the veins will then be detected

(fig. 1). These become more distinct, and if the weather is moist an obscure violet coating of the spores may be noticed on the under side of the spots. The disease progresses from the center of the hill outward, the young leaves at the tips of the branches living longest. It spreads slowly in bright weather, but under the more favorable conditions afforded by cloudy, humid weather it often develops with the greatest rapidity, so that the fields quickly become as if scorched by fire.

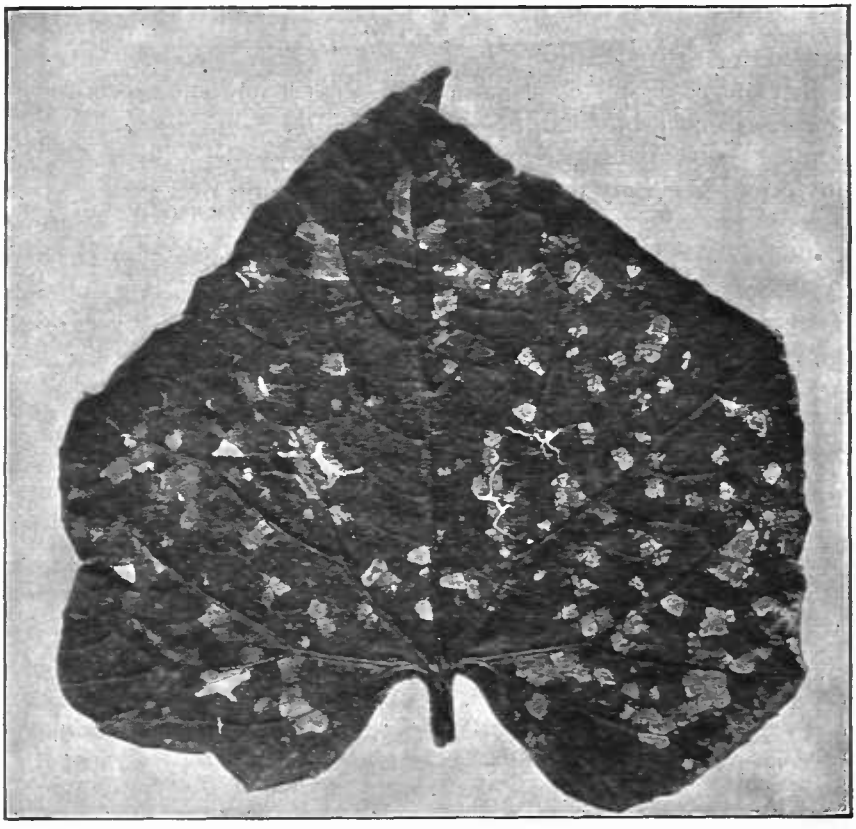

FIG. 1.—Cucumber leaf attacked by downy mildew.

Downy mildew has been known in this country since 1889, and in various years has caused serious loss, especially to the pickle industry on Long Island and in Ohio and other States. It is also destructive to cucumbers in greenhouses.

Cause.—Downy mildew is caused by a parasitic fungus closely related to the destructive downy mildews of grape, onion, etc., and to the late blight of potato. So far as known, it is spread entirely by its conidia, or summer spores, produced on the lower surface of diseased leaves. These are blown about by the wind, but are very thin-walled,

delicate bodies, which perish quickly when dried. No oospore or resting stage is known, and there is consequently no evidence that the fungus lives over in dead vines or in the soil, and no logical reason for destroying the vines or for selecting fresh land for the crop, aside from questions of soil fertility.

Conditions favoring development.—The disease lives through the winter in Florida and probably spreads northward each summer. There is also good evidence that it lives over in greenhouses, which may later become the centers of local epidemics.

The earliest appearance of the disease in South Carolina in 1905 was May 1. It usually appears in that latitude during June. It does not reach Ohio until August 1, while New York and New England are visited later in August. The date of appearance and the severity of the outbreak seem to be governed mainly by the weather. During unusually dry seasons the disease may be entirely absent, while warmth and moisture, especially warm, cloudy nights, soon lead to its development and result in the greatest loss. Any weakness of the plant appears also to predispose it to attacks of downy mildew. Cold weather during spring, when the plants are small, is unfavorable for this reason. The plant also becomes more susceptible when the bearing of fruit is imposing an additional strain upon it. Liberal fertilizing and careful attention to cultivation should be given to keep the vines strong and vigorous.

LEAF-BLIGHT.

Alternaria brassicæ nigrescens Pegl.

The above-named fungus is the usual cause of leaf-blight of muskmelons or cantaloupes throughout the country, though downy mildew and anthracnose also occur and sometimes are associated with the leaf-blight.

Appearance.—Leaf-blight begins in small, round spots, which usually show faint concentric rings. These spots enlarge and their effect is very quickly visible on the leaf. The cantaloupe leaf in particular, owing to its thin and delicate structure, will curl at the margins and shrivel up in a few days. (See fig. 2).

Cause.—The disease is caused by a fungus closely related to the species causing early blight of potato, leaf-blight of cabbage, etc. It was first studied in this country by Dr. Erwin F. Smith in 1892. The same year it was described from Italy by Peglion as *Alternaria brassicæ*, var. *nigrescens*. Later the same fungus was named *Macrosporium cucumerinum* by Ellis and Everhart, and has been referred to under this name in several experiment station bulletins.

Leaf-blight is spread by spores borne on the upper side of the leaves and carried by the wind and the other usual agents. No per-

fect stage has been discovered, but it is probable that the fungus lives over winter in the fields, and the experience of farmers indicates that it is worse on fields repeatedly planted in melons. Rotation of crops is therefore advisable to lessen its ravages. This disease does not, as a rule, develop in the field as rapidly as the downy mildew, but in warm, humid weather it spreads quickly and does great harm. The ripening of the melons is hastened, their quality greatly injured, and the total crop diminished.

ANTHRACNOSE.

Anthracnose occurs on the leaves and stems of cucumbers and muskmelons, and on the leaves, stems, and fruits of watermelons.

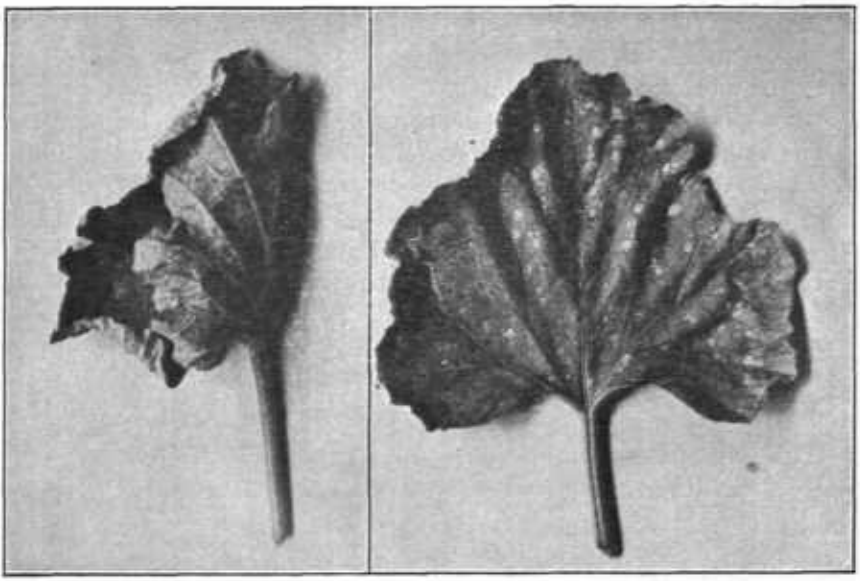

FIG. 2.—Cantaloupe leaves showing effect of leaf-blight.

It also attacks other cucurbits. It is common and sometimes injurious, but is relatively of less importance than the downy mildew or the leaf-blight.

Appearance.—Circular dead spots from one-fourth to one-half inch in diameter are formed on the leaves (fig. 3). They are distinguishable from the angular spots of the downy mildew, except when the latter have grown very slowly. On the stems anthracnose causes elongated, discolored, and shrunken areas, which finally lead to the death of the branch. Watermelon fruits are often badly spotted by this disease, and much injury is done to the vines.

Cause.—Anthracnose is due to the fungus *Colletotrichum lagenarium* (Pass.) Ell. & Hals., which is related to the fungi causing

anthracnose in grapes, raspberries, cotton, and beans, and the bitter rot of the apple. It is spread freely by the conidiospores which are produced in abundance in the spots on the leaves and fruit. A perfect form is not known, but the field evidence indicates that the disease persists in the dead vines or elsewhere in old fields, and the destruc-

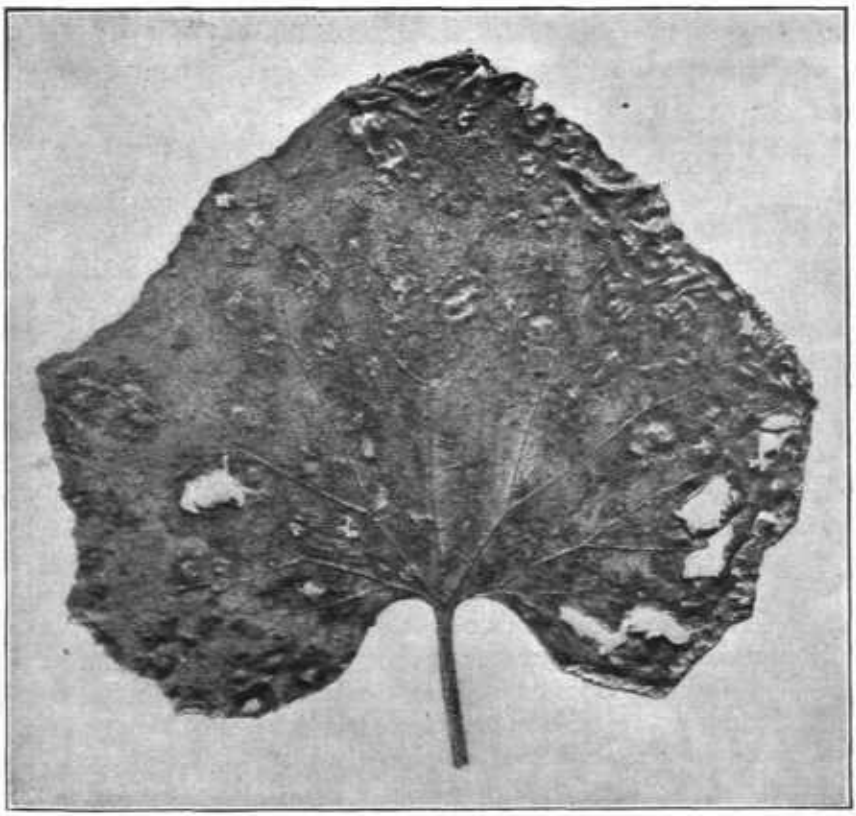

FIG. 3.—Cucumber leaf attacked by anthracnose.

tion of such vines, together with rotation of crops, is recommended as a means of prevention.

OTHER LEAF-SPOT DISEASES.

The three fungi previously mentioned are the most common and injurious cucurbit pests, but several minor troubles occur and cause slight losses, which could be prevented by spraying. They hardly require separate mention in a publication of this character, as it would be difficult for the practical grower to distinguish them. The fungi causing them are *Phyllosticta cucurbitacearum* Sacc., *Cladosporium cucumerinum* Ell. & Arth., *Acremonium* sp., and *Cercospora citrullina* Cke. The powdery mildew of the cucumber, *Erysiphe polygoni* DC., is common in greenhouses, but infrequent outdoors.

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It forms a powdery white coating on the leaves without causing a spot, and is thus easily distinguished from the downy mildew.

Other troubles encountered in the field and greenhouse are stigmonose, due to an attack of aphides; wilt and leaf-curl, due to overfertilizing, etc., and root-knot, caused by nematodes.

WILT.

There is a form of wilt sometimes met with in greenhouses which is due to overfertilizing.

Another distinct cucurbit disease is prevalent in the North and West, and is mentioned to avoid confusion with the leaf-blights already described. When a melon, cucumber, or squash vine suddenly wilts throughout its length and dies without appreciable spotting of the leaves the trouble is usually caused by a species of bacteria, *Bacillus tracheiphilus* Erw. Sm., which enters and clogs the water-carrying vessels of the stem. This wilt disease is spread by leaf-eating insects and probably also by soil infection. Rotation of crops is advised, together with the addition of an insecticide like Paris green to the Bordeaux mixture. The Bordeaux mixture itself acts as a repellant to the insects and helps to check the spread of wilt. There is experimental evidence showing the value of spraying for wilt, but it should not be expected that this disease will be as fully controlled in this way as the leaf-blights. It is also important to pull and burn diseased vines as soon as they begin to wilt, in order to lessen the spread of the disease.

Fusarium wilt.—Another wilt disease of cucumbers and muskmelons similar in appearance to that described in the preceding paragraph is due not to bacteria, but to a fungus related to the one causing the watermelon wilt, *Neocosmospora vasinfecta*, var. *nivea*. This disease has been little studied, and is apparently not of great importance. Spraying will not prevent this form of wilt, and rotation of crops is essential.

DISEASE RESISTANCE.

The possibility of securing strains or varieties of cucumbers and melons resistant to the leaf-blight fungi has been considered and some experiments have been made. In connection with experiments recently made at Charleston, S. C., all obtainable varieties of cucumbers and muskmelons were planted and left unsprayed to determine their relative susceptibility. All were attacked, and while differences in degree of infection were noted, all were badly injured. One kind of cucumber, the Japanese climbing variety, was more resistant than the others and remained living after they were dead. There is little doubt that well-directed efforts in plant breeding would result in the

development of resistant or partially resistant strains. This would require several years of effort. The market requirements are for particular types of fruits, and a disease-resistant strain would have to conform to these demands. While it is very important that efforts should be made to develop such desirable qualities, it appears that resistance to leaf-blights among cucurbits is at present so slight as to amount to very little and that spraying must be the main protection of the farmer.

SPRAYING EXPERIMENTS.

That diseases of cucumbers and melons can be controlled by spraying with Bordeaux mixture has been successfully demonstrated by several investigators during recent years. The first recorded experiments were made by Col. A. W. Pearson in 1888 and 1889 under the direction of the Department of Agriculture, using Bordeaux mixture for melon blight, but without definite results. Dr. B. D. Halsted, of the New Jersey Experiment Station, conducted a series of annual experiments, beginning in 1894, which showed the efficiency of Bordeaux mixture and later of soda-Bordeaux mixture against downy mildew and anthracnose of cucumbers.

Prof. F. C. Stewart, of the New York State Experiment Station, conducted field experiments with cucumbers on a more extensive scale on Long Island in 1896, 1897, and 1898, using Bordeaux mixture to control the downy mildew. He showed the first year that by an expenditure of $9.50 per acre there was an increased net profit of $163.50 per acre due to protection from disease, the cucumbers produced being sold for pickles. The experiments of the two following years corroborated these results, and the Long Island growers have since then continued spraying as a regular practice.

Prof. A. D. Selby, of the Ohio Experiment Station, conducted experiments along the same line in 1897 and 1898. He showed that cooperative spraying experiments gave an increase of 75 bushels per acre of cucumbers for pickling over unsprayed vines attacked by downy mildew. Anthracnose and other leaf-blights were also controlled in most cases.

Dr. W. C. Sturgis, at the Connecticut State Experiment Station, sprayed muskmelons in 1898 with complete success in controlling leaf-blights, though the bacterial wilt did not yield to the treatment.

Mr. H. H. Griffin, of the Colorado Experiment Station, conducted spraying experiments on cantaloupes at Rockyford in 1899, 1900, and 1901 with uniform success in controlling the leaf-blight with Bordeaux mixture. The average cost per acre was $4.47 in one instance, and less in others.

Prof. H. H. Hume, at the Florida Experiment Station, sprayed in 1900 for the downy mildew of the cucumber with success.

Prof. G. P. Clinton, at the Connecticut State Experiment Station, conducted experiments in 1902 and 1903 which led him to the following conclusions:

(1) When the downy mildew is very severe, spraying is useless; (2) when the seasons are cold and damp but fungi not usually destructive, spraying may show some benefit to the foliage, but the unfavorable influence of the weather will not be overcome by this treatment; (3) warm, fairly dry seasons (moisture well distributed) are necessary for the best development of muskmelons in Connecticut, and such seasons are not likely to bring serious attacks of fungi, so that spraying in these seasons is of little or no advantage; (4) everything considered, spraying muskmelons scarcely merits recommendation in this State. These statements do not apply to the cucumber, which, without doubt, is often benefited by thorough spraying.

Mr. E. R. Bennett, at the Connecticut (Storrs) Experiment Station, performed similar experiments in 1903, which were successful in controlling the downy mildew.

The extensive field experiments conducted by this Department at Charleston, S. C., upon which the recommendations in this bulletin are based, showed that downy mildew of the cucumber can be controlled even during a most unfavorable season when the work is done with sufficient thoroughness.

PRACTICAL CONCLUSIONS RELATIVE TO METHODS OF SPRAYING.

MANNER OF PLANTING.

It is of great importance for economy of time and labor in spraying to adjust the rows in planting so as to facilitate the use of spraying machinery. This is particularly necessary when the acreage is large and geared sprayers are to be used. Distances in planting are often matters of local custom that might be modified without loss. The rule should be to plant in long rows with single vines at close intervals in the row, rather than in hills. Cucumbers, for instance, are planted in the South in rows 6 feet apart, with the vines 18 inches apart in the row. Cantaloupes or muskmelons would require about 24-inch spaces in 6-foot rows. During cultivation the vines should be encouraged to spread along the rows, and by the use of a vine turner an open alley 1 foot wide can be preserved throughout the season. This will allow the sprayer to be driven through the field and will also permit the passage of the pickers with less injury than when the vines are planted in hills. If the wheels of the sprayer occasionally nip off the ends of branches that have straggled across the path, the loss is insignificant when compared with the benefit derived from spraying.

At the ends of the rows space must be left to turn the sprayer. To reduce this wasted area and to save time in turning, the rows should be as long as possible.

Geared sprayers are usually made with 6-foot axles to cover one row of vines or two rows of potatoes. In special cases, as when the vehicle used has a width of less than 6 feet, the distance between the rows should be made to correspond. If, for instance, the outfit is to be mounted on a barrel carried in a farm wagon and the spray distributed through long hose, a roadway may be left at every eighth or ninth row to permit the passage of the wagon, and this space may be planted, as suggested by Stewart, with cabbages or other low crops. As a matter of field practice, however, it would be as well to plant this roadway with melons or cucumbers like the rest of the field and keep them in a narrow bed. The hill or check system of planting involves either the use of hand sprayers or greater injury to the vines. Intercultural crops, such as beans planted between the rows of cucumbers, are objectionable when spraying is to be done, as they hinder the use of the spray cart and may also be injured by the Bordeaux mixture.

EQUIPMENT.

The character of the apparatus required for spraying vine crops depends upon the area to be sprayed. It may be classified for our discussion under three heads, viz, equipment for gardens, for small fields, and for large fields.

Garden Sprayers.

When less than an acre of vines is to be sprayed, a small hand pump designed to spray from a bucket is all that is needed. Modifications of this are on the market, with the pump mounted in a covered bucket to be carried in the hand, or as a knapsack sprayer, which is perhaps the most convenient form of small pump for general use. A good compressed-air sprayer serves much the same purpose at a less cost. Nearly all of the sprayers found on the market would be improved by lengthening the hose to 6 feet or more. The nozzle should be of the Vermorel type.

Field Sprayers.

For fields of from 1 to 5 acres a barrel sprayer is recommended. This consists of a hand pump mounted in a barrel or tank and equipped with two leads of $\frac{3}{8}$-inch hose 25 feet long, each with a 4-foot extension made from $\frac{1}{4}$-inch gas pipe, and a double Vermorel nozzle. The barrel should be mounted on a two-wheeled cart having a 6-foot axle. Two horses are required when driving over vines in 6-foot rows. Three men do the work. One is expected to drive and pump, while the other two manipulate the nozzles. The outfit is stopped while the vines within reach are sprayed, then driven forward about 30 feet and stopped again. On an average

in actual field practice 3 to 4 acres per day can be sprayed in this way, applying 200 gallons of Bordeaux mixture per acre. To keep the long hose off the vines two poles about 10 feet long may be pivoted to the bed of the cart so as to swing at an angle over the wheel and carry the hose, as shown in figure 4. The pump for this outfit should be of good capacity, with brass valves. A "Y" shut-off discharge connection on the pump is a convenience for stopping the spray at any time. Carts of this kind are usually homemade, but they are on sale by some dealers. The evener and neck yoke should be 6 feet long, except that early in the season when the vines are small it will be found that the ordinary length can be used to better advantage. This outfit is excellently adapted for spraying small

FIG. 4.—Hand barrel sprayer, with cart, in operation in a cucumber field.

fields of potatoes and for general orchard work, and is invaluable on the average farm. Instead of using a special cart some may prefer to set the barrel in an ordinary farm wagon or to mount it on a pair of low wheels and push it about by hand.

Geared Sprayers.

When there are more than 5 to 10 acres of vine crops and potatoes to be sprayed a suitable horsepower sprayer will, by economy of time and labor, considerably reduce the cost per acre and, if properly constructed and operated, will do more efficient work than hand labor. The saving of labor on a large truck farm, for instance, is especially important, as field work is usually done under the high pressure incident to the cultivation and shipment of strawberries,

beans, beets, cabbages, potatoes, etc., during the cucumber season. Reliable laborers are scarce, and the power sprayer will permit one man to do four to five times the work of three men and a hand pump by covering 15 acres per day instead of 3 or 4 acres. The time saved is equally valuable, as spraying must often be done at intervals between other duties, and in case of continued rainy weather the ability to spray the whole field promptly may mean the preservation of the crop. Less Bordeaux mixture is consumed by a power sprayer. One hundred gallons per acre should be applied, and this will cover every leaf with a fine mist in an ideal manner, while the hand sprayer operated by the average laborer will require 200 gallons per acre, owing to the excess applied to some leaves in order to insure reaching all. Experience has also shown that with hand labor there are occasional vines entirely overlooked, and that, on the whole, machine work is more effective. This should not be interpreted to mean that all geared sprayers would be so effective. Many machines on the market have been developed for applying arsenites to potatoes and are not adapted for putting Bordeaux mixture on cucumbers or melons. The primary requisite of a sprayer for the latter purpose should be the ability to apply 100 gallons of Bordeaux mixture per acre through Vermorel nozzles. No machine with a capacity of only 25 to 50 gallons per acre can be expected to protect tender vines from such actively parasitic fungi as those which attack cucurbits, for it is impossible to make so small a quantity of solution cover every part of every leaf. Many other points affecting durability of construction and ease of operation are also important, and each of these will be discussed in turn. The writer is not aware that there is now on the market any power sprayer especially fitted for vine crops. The purchaser will usually be obliged to purchase a potato sprayer and have such modifications made as may be required. A suitable outfit will consist of a two-wheel two-horse cart, with a 6-foot axle, carrying a 100-gallon tank, with double-cylinder pump, operated from the axle by sprocket chain; air chamber; agitator; and row sprayer for 3 rows of cucumbers or 6 rows of potatoes. (See fig. 5.) The parts are discussed in detail as follows:

Pump.—A pump with double vertical cylinders, or its equivalent in other styles, is advised. A large capacity is essential. All working parts should be of brass or bronze, including valves, which should be easily accessible. A hand lever, though rarely used on a field sprayer, is occasionally convenient.

Air chamber.—The air chamber should be of good size, but not too large, as liquid and sediment will tend to accumulate in it. Provision should be made for draining and cleaning the air chamber.

Pressure gauge.—A high pressure, 40 to 100 pounds, is required to accomplish best results in spraying. A pressure gauge connected

with the air chamber is therefore essential in order that the operator may know what his machine is doing, and also to reduce the danger of an explosion from too much pressure.

By-pass.—Every power sprayer must be fitted with a by-pass, or safety valve, arranged so that the liquid will be discharged back into the tank whenever the pressure reaches a given point. Attention should be paid to this device to see that it is properly adjusted.

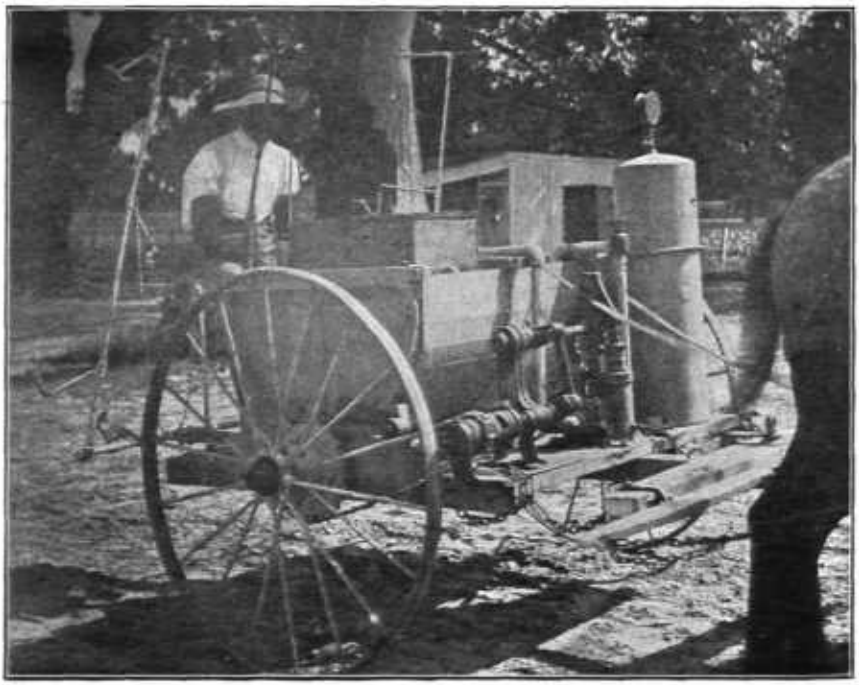

FIG. 5.—Front view of machine sprayer.

Piping.—The best sprayers are equipped with brass piping, because iron is rapidly corroded by the copper compounds used in spraying, and the flakes from the inside of the pipe are likely to clog the nozzles. On the other hand, iron pipe is much cheaper, and if the outfit is washed out after each using there is little trouble during the spraying season. Iron pipes are likely to rust rapidly and fill with sediment when not in use, and a sprayer should never be used in the spring until all the pipes have been taken apart and thoroughly cleaned inside. It costs very little to replace iron piping, and the use of brass, though preferred, is therefore not essential.

Row sprayer.—This refers to the device employed to hold the spray nozzles over the rows to be sprayed, including the pipes leading from the discharge pipe to the nozzles. Rubber hose is sometimes em-

ployed for the latter purpose, but in most cases an iron pipe attached to the rear of the platform and extending laterally over the rows on either side carries the nozzles at the ends of arms of the proper length. (See fig. 6.) The main pipe is three-fourths inch in the center, reduced to one-half inch, and again to three-eighths inch on either side. Joints behind each wheel, made by inserting two elbows and a nipple, allow the extending ends to be folded up when driving to and from the field. For spraying potatoes it is sufficient to attach the nozzles directly to this pipe so that they point back and down, but for vine crops, where the rows are wide and the spread of the vines variable at different periods and in different fields, it is necessary to provide for adjusting the nozzles so as to spray either a narrow

FIG. 6.—Spraying three rows of cucumbers with machine sprayer.

row at the beginning or the whole space at the end of the season. This may be accomplished by placing the nozzle on an extension made from two sections of one-fourth-inch pipe 6 to 8 inches long, united by a hinge joint. This hinge may be made from two iron elbows and a nipple, but it is much better to have a brass swivel joint, secured by a thumbscrew, as shown in figure 7. Additional adjustments can be made at the nozzle. The length of the arm (*a*, fig. 7) allows the center nozzles to be elevated to cover a wide row, which is important when cucumbers are grown on a high ridge or bed. Three rows of vines are covered at one time, and each row receives the spray from above and from either side. The nozzles at the side should be carried nearer the ground and directed sideways. In this way much of the spray will reach the under sides of the leaves.

The row sprayer is usually fixed immovably to the platform of the cart. This was found to be a serious objection in spraying cucumbers, as the nozzles were thrown off the rows whenever the course of the machine varied from a straight line, which was rather often on irregular ground early in the season. The same thing occurred in turning at the ends of the rows and when operating on windy days. To obviate this difficulty, the device illustrated in figure 7 was attached, to allow the whole row sprayer to be moved from side to side at the will of the operator. This was accomplished by a wooden frame (*a-b-c-d*), pivoted to the rear platform at *e-e* and supporting the row sprayer by iron clamps at *a* and *d*. The foot lever *f-f* is ele-

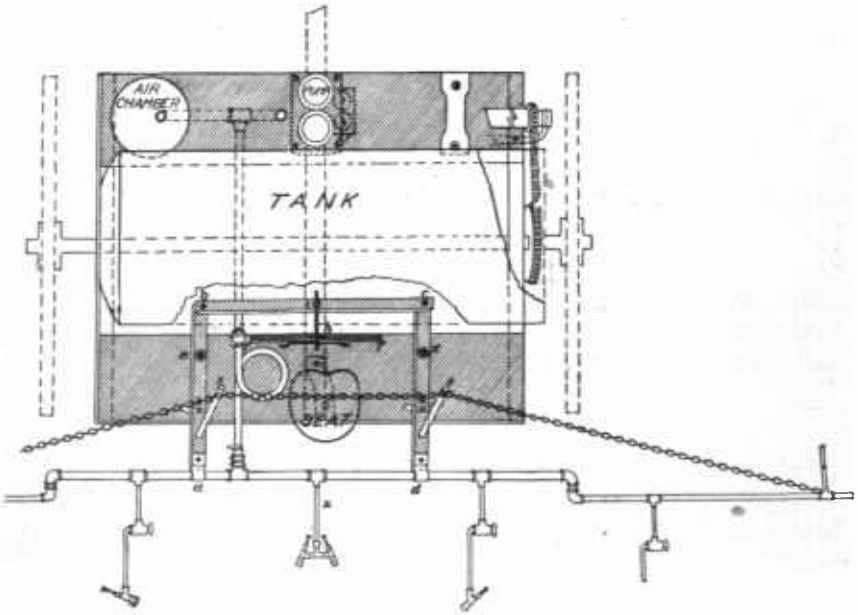

FIG. 7.—Diagram showing arrangement of row sprayer on machine.

vated by an iron brace from the platform, and the rigid iron projection (*h*) passes through an eyebolt in the wooden bar *b-c* at *i*. When the team swerves to the left, the driver, by pressing the lever with his right foot, moves the row sprayer to the right and brings the nozzles again over the row. Rollers at *k-k* relieve the friction of the frame on the platform, and little force is required to move it. To upright iron standards made from one-fourth-inch gas pipe (*s-s*) a light jack chain is attached to support the ends of the row sprayer. These chains are within the reach of the driver on the seat in case the pipe must be raised to pass over an obstacle or through a gateway. This device for securing lateral movement of the row sprayer is not absolutely essential, but is simple in construction and adds to the efficiency of the outfit. This is particularly the case on windy days when

the entire spray is blown to one side, as it is easy to overcome what would otherwise be an insurmountable difficulty by throwing the row sprayer to windward. On turning at the end of the row it is quickly thrown over to the other side. This device is not patented, but has been in use two years.

Nozzles.—The best results were obtained by using 6 nozzles to the row, 2 over the center and 2 on each side. Three nozzles might suffice for young vines, but less than this number would never do thorough work, and when the vines cover the ground 6 to the row is not too many. As far as possible the nozzles should be set at different angles, pointing forward, back, and sideways, so that their spray does not meet. The vines will then be struck from every direction, and no portions of them can escape the treatment. A fine spray is desired for this work, and nozzles of the Vermorel type are best.

Spray cart.—This consists of a plain iron and wood frame, balanced on an axle 6 feet long. The wheels should be fairly high and very strong, with wide tires. The gearing should be arranged to draw from both wheels and should be simple in construction and strong. The fact that a spray cart must be driven very slowly should be borne in mind, and the pump should therefore be geared relatively high. The weight of a man on the seat should balance the load. Two horses are required. The evener and neck yoke should be 6 feet long, except early in the season, when the ordinary length is preferable, as the team will keep a straighter course when driven close to the beds.

Tank.—The best size of tank is one capable of holding 100 gallons. A larger one is heavy for two wheels and a smaller size requires too frequent filling. The form of tank is less important, but the half-round style is preferable to the upright. The best tanks are of cypress and those especially constructed for the purpose can be found in the market.

Agitator.—A mechanical agitator is provided with the best outfits. It should not be of iron unless thickly covered with asphalt paint, and it should work easily.

Strainer.—A good strainer is indispensable, as much clogging of the nozzles follows if any large particles are admitted to the spray tank. The most convenient form for a large tank is V-shaped, set permanently into the tank under the lid. The strainer should be large, with at least 1 square foot of surface. Brass-wire cloth, 18 meshes to the inch, is the best material. For barrel sprayers use a similar V-shaped strainer set in a wooden box, into the bottom of which a short section of 2-inch iron pipe is screwed for an outlet. It will be a further convenience if a second strainer of coarser mesh is provided for straining the stock lime into the dilution barrel.

ADAPTING POTATO SPRAYERS TO VINE CROPS.

Most of those who prepare to spray as directed in this bulletin will find it desirable to use machines made primarily for potatoes. This can usually be done by a change in the row sprayer, provided that the pump is of sufficient capacity to do the work. The sprayer must apply at least 100 gallons per acre through Vermorel nozzles. One that will apply 50 gallons per acre could be run twice over the same field. There is always a tendency, however, on the part of workmen to do superficial spraying. To do good spraying, a very slow-walking team should be chosen, and the pump should be geared correspondingly high so as to maintain full pressure at a slow speed. Few potato sprayers will work when driven slowly, on account of a lack of pressure. On the other hand, a cucumber sprayer made as here directed would give excellent results on potatoes, spraying 6 rows 3 feet apart with 2 nozzles directed on each row. It is most profitable to use the best implements, and the principal reason why sprayers of adequate capacity are scarce is that the public has not yet been educated to demand them.

PREPARATION OF BORDEAUX MIXTURE.

Bordeaux mixture is made from copper sulphate (bluestone) and lime. The copper sulphate is the fungicidal agent and the lime is added to prevent injury to the foliage. It should be made fresh before using each time. The proportions of the ingredients are varied according to the crop sprayed. For young cucumbers the formula advised is as follows:

Copper sulphate	3 pounds.
Fresh stone lime	6 pounds.
Water	50 gallons.

This formula is safe for tender vines in the greenhouse or outdoors, and should be used at the start. The excess of lime will tend to prevent accidental injury from errors due to inexperience. A weaker mixture than this is not advisable. Well-established outdoor vines are not injured by a stronger mixture, and it is advised that later in the season 4 pounds of copper sulphate and 4 pounds of lime to 50 gallons of water be used. For potatoes the usual formula is 6 pounds of copper sulphate, 4 pounds of lime, and 50 gallons of water.

It is most convenient in practice to have stock solutions containing 2 pounds per gallon of the respective ingredients. In preparing such solutions, take a 50-gallon barrel and suspend near the top a coarse sack containing 100 pounds of crystallized or granulated commercial copper sulphate. Fill the barrel with water and the whole quantity will be dissolved in a few hours. In another barrel place 100

pounds of lime freshly slaked. For this purpose choose clean stone lime of the best quality. Slake thoroughly by the addition of small quantities of water at a time as needed, stirring until all small lumps are slaked. After the slaking is completed keep the paste covered with water. These stock preparations can be kept for an indefinite time if water is added to replace that lost by evaporation. Both should be stirred very thoroughly before taking any out. Both the copper sulphate and the lime should be diluted before they are combined, as the physical condition of the mixture varies greatly according to the manner of making, and its effectiveness is in a large degree dependent on its physical condition. A poorly made Bordeaux mixture settles quickly, is more apt to clog the nozzles, and does not adhere so well to the foliage.

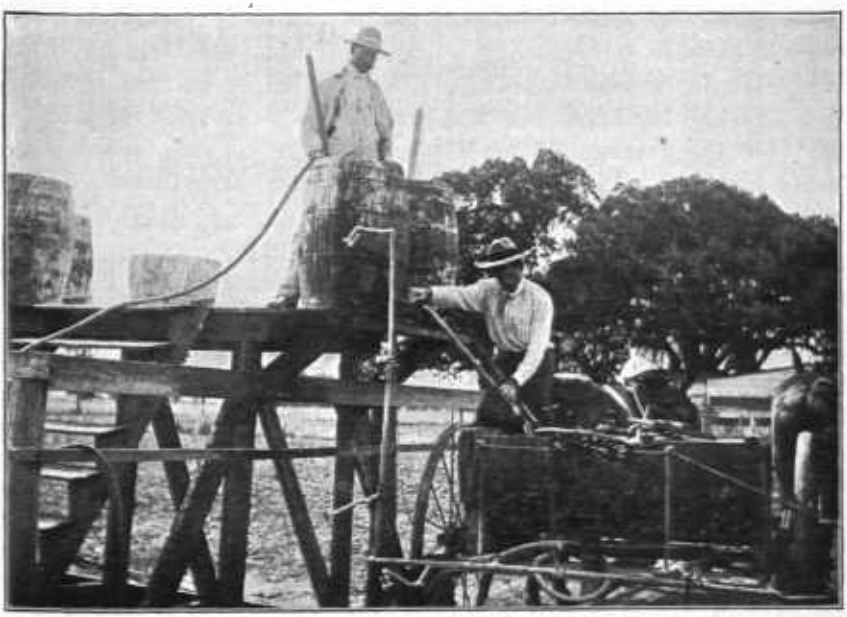

FIG. 8.—Platform for loading machine sprayer.

For convenience in making and handling the mixture a platform high enough to permit the spray cart to be driven underneath should be built. (See fig. 8.) This should be located near the water supply, if possible, so that water can be pumped directly into the barrels on it. On the platform place the stock barrels and two other dilution barrels. A hose or trough should lead from these barrels to the spray tank. To make 50 gallons of Bordeaux mixture according to the 3–6–50 formula advised on page 20, stir well both stock solutions. Pour into one dilution barrel 1½ gallons of the copper-sulphate solution and add water to make 25 gallons. Strain into the other dilution barrel 3 gallons of the lime milk and add water to make 25

gallons. Then allow both to run together through a strainer into the spray tank. Stir well and apply at once. To make the 4–4–50 formula take 2 gallons of each stock preparation.

COST OF SPRAYING.

The cost of spraying will vary greatly in different sections, according to cost of materials, efficiency of labor, etc. The first cost of a power sprayer similar to that described in this bulletin will be about $150. The cost of applying the mixture can be reduced by thorough organization and the use of labor-saving appliances. Stewart, in experiments on Long Island, found the cost of seven applications by hand to be $9.50 per acre, while Selby, in Ohio, computed the cost of the same number of applications by hand to be $7.70 per acre. In the writer's experience, hand work has been fully as expensive as these figures indicate, but spraying by machinery has been cheaper. The wages of the operator were $2 per day, his helper was paid 75 cents per day, and the teams cost $2.25 per day, a daily total for labor of $5. On the average, 15 acres per day were sprayed, making the labor cost 33 cents per acre. Assuming that 100 gallons per acre were applied, the bill would be:

Copper sulphate, 6 pounds, at 7 cents per pound	$0.42
Lime, 12 pounds, at 1 cent per pound	.12
Total cost of material	.54
Total cost of labor	.33
Cost per acre of each application	.87
Cost per acre of six applications	5.22

There should be added for interest on investment, repairs, and depreciation of outfit, $1 per acre, which increases the total cost to $6.22 per acre.

PROFITS.

Professor Stewart obtained a net profit of $163.50 per acre from spraying cucumbers on Long Island. In the experiments at Charleston, S. C., conducted by the writer in 1905, the crop of about 150 baskets per acre was worth about $115 net, and nearly this entire amount, plus the cost of cultivation, would have been lost had spraying not been attempted on account of the severity of the disease. The cucumber and melon crops as usually grown represent intensive culture and a large money value per acre, which justifies considerable expenditure for protection by spraying. Half-hearted or misdirected efforts will not succeed, but only add to the loss.

SPRAYING, A FORM OF INSURANCE.

While the diseases described in these pages do not occur every year, experience has shown that they recur frequently, and in years of serious epidemics the profits from spraying are so great that the grower can afford to spray regularly as an insurance against loss. For instance, the profits from the spraying done in 1905 at Charleston will pay for repeating the work every year for at least eighteen years.

WHEN TO BEGIN SPRAYING.

In order to be absolutely safe, it is best to make the first application early, when the vines begin to run, as it is nearly impossible to check downy mildew after it is once established in a field. A grower who understands the relation of warm and moist weather to the disease and will watch carefully for the first appearance can, however, save one or two of the earlier applications in dry seasons. The date of the first appearance varies greatly in different seasons and is not a safe guide.

INTERVAL BETWEEN SPRAYINGS.

There is also room for some judgment as to the proper interval between sprayings. If the vines are growing very slowly and the weather is dry, once in ten days will be sufficient. As the critical time approaches and the blight is actually in neighboring fields, closer attention must be given and the spraying should be repeated weekly. If the vines are growing rapidly, this is not often enough, and it is better to spray twice a week. The aim should be to keep all the leaves protected by a covering of the Bordeaux mixture. There is a tendency to relax vigilance toward the end of the season, but this should be avoided. When the disease is in the field and all around, more protection should be given the vines.

EFFECT OF BORDEAUX MIXTURE ON THE FRUIT.

The possibility of objection being made to the stain of the Bordeaux mixture on the fruit has been considered. In the case of cucumbers, the fruits are so protected by the leaves and develop so rapidly that little stain appears, and this is easily rubbed off. Several thousand bushels were harvested from the fields sprayed in 1904 and 1905 and no objection was made by the purchasers to the slight stain. Such objections have no valid foundation, for it has been conclusively demonstrated that there is no danger of poisoning from eating sprayed fruits. Even were the skins eaten, which is not true with melons and cucumbers (except in the case of pickles), an enormous

quantity would have to be eaten before any appreciable amount of copper could be taken.

CONTROL IN THE GREENHOUSE.

Both downy mildew and anthracnose attack cucumbers grown under glass and sometimes do much injury. It should be less difficult, however, to prevent these diseases in a greenhouse, where the conditions are more fully under control, than in the open field. The houses are sometimes started early in the fall, while outdoor crops in the neighborhood are still affected by disease. There is especial danger in such cases that downy mildew or anthracnose will gain a foothold and persist through the winter, making the greenhouse a center for the infection of near-by fields the next spring. In a locality where these diseases prevail it would be well to burn sulphur in the houses before any plants are put in, bearing in mind that its fumes are very destructive to all vegetation. Give the beds a thorough cleaning, and whitewash all exposed walls and woodwork. The management of the houses is an important factor in controlling these troubles. Lack of ventilation and overwatering favor the spread of disease, but where the requirements of the cucumber crop are fully understood fungi rarely give much trouble. Should any appear, spraying with Bordeaux mixture must be resorted to. The 3–6–50 formula, advised on page 20, should be used, and the mixture should be applied thoroughly. It is important that the lower as well as the upper sides of the leaves be covered. Repeat the applications weekly.

Powdery mildew of the cucumber, a white surface covering of the leaves, is common in some houses. Its presence indicates excessive moisture and lack of ventilation. The best remedy is attention to these points, together with the evaporation of sulphur, best accomplished by making flowers of sulphur into a paste and applying this to the hot-water pipes or evaporating it in a shallow pan placed on a sand bath.

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